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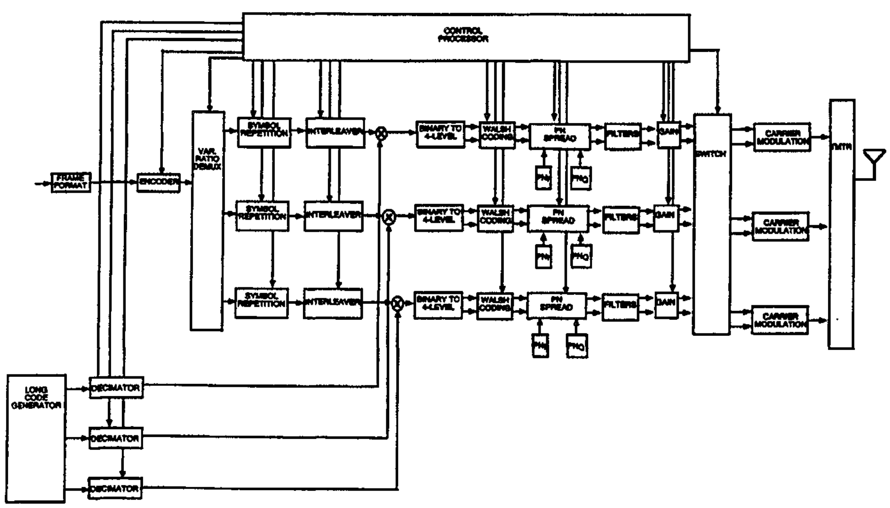

(57) Abstract

A method of an apparatus for transmitting data in a multiple carrier system comprises encoding data and dividing the resulting encoded symbols for transmission on different frequencies. The transmitter comprises a control processor (50) for determining the capacity of each of a plurality of channels and selecting a data rate for each channel depending on the determined capacity. A plurality of transmission subsystems (56 to 72) are responsive to the control processor (50). Each transmission subsystem is associated with a respective one of the plurality of channels for scrambling encoded data with codes unique to the channel for transmission in the channel. A variable demultiplexer (56) under the control of the control processor (50) demultiplexes the encoded data into the plurality of transmission subsystems at a demultiplexing rate derived from the data rates selected for the channels by the controller. In one embodiment of the transmission subsystems, the encoded symbols are provided to a symbol repetition unit (58) which keeps the symbol rate of data to be transmitted fixed. In another embodiment, no symbol repetition is provided and variable length Walsh sequences are used to handle data rate variations.

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A METHOD OF AND APPARATUS FOR TRANSMITTING DATA IN A MULTIPLE CARRIER SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to a method of and apparatus for transmitting data in a multiple carrier system. The present invention may be used for maximizing system throughput and increasing signal diversity by dynamically multiplexing signals onto multiple carriers in a spread spectrum communication system.

II. Description of the Related Art

It is desirable to be able to transmit data at rates which are higher than the maximum data rate of a single CDMA channel. A traditional CDMA channel (as standardized for cellular communication in the United States) is capable of carry digital data at a maximum rate of 9.6 bits per second using a 64 bit Walsh spreading function at 1.2288 MHz.

Many solutions to this problem have been proposed. One solution is to allocate multiple channels to the users and allow those users to transmit and receive data in parallel on the plurality of channels available to them. Two methods for providing multiple CDMA channels for use by a single user are described in co-pending U.S. Patent Application Serial No. 08/431,180, entitled "METHOD AND APPARATUS FOR PROVIDING VARIABLE RATE DATA IN A COMMUNICATIONS SYSTEM USING STATISTICAL MULTIPLEXING", filed April 28, 1997 and U.S. Patent Application Serial No. 08/838,240, entitled "METHOD AND APPARATUS FOR PROVIDING VARIABLE RATE DATA IN A COMMUNICATIONS SYSTEM USING NON-ORTHOGONAL OVERFLOW CHANNELS", filed April 16, 1997, both of which are assigned to the assignee of the present invention and are incorporated by reference herein. In addition, frequency diversity can be obtained by transmitting data over multiple spread spectrum channels that are separated from one another in frequency. A method and apparatus for redundantly transmitting data over multiple CDMA channels is described in U.S. Patent No. 5,166,951, entitled "HIGH CAPACITY SPREAD SPECTRUM CHANNEL", which is incorporated by reference herein.

The use of code division multiple access (CDMA) modulation techniques is one of several techniques for facilitating communications in which a large number of system users are present. Other multiple access communication system techniques, such as time division multiple access (TDMA), frequency division multiple access (FDMA) and AM modulation schemes such as amplitude companded single sideband (ACSSB) are known in the art. However, the spread spectrum modulation technique of CDMA has significant advantages over these other modulation techniques for multiple access communication systems.

The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Patent No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS", assigned to the assignee of the present invention and incorporated by reference herein. The use of CDMA techniques in a multiple access communication system is further disclosed in U.S. Patent No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein. Code division multiple access communications systems have been standardized in the United States in Telecommunications Industry Association Interim Standard IS-95, entitled "Mobile Station-Base Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System", which is incorporated by reference herein.

The CDMA waveform by its inherent nature of being a wideband signal offers a form of frequency diversity by spreading the signal energy over a wide bandwidth. Therefore, frequency selective fading affects only a small part of the CDMA signal bandwidth. Space or path diversity on the forward/reverse link is obtained by providing multiple signal paths through simultaneous links to/from a mobile user through two or more antennas, cell sectors or cell-sites. Furthermore, path diversity may be obtained by exploiting the multipath environment through spread spectrum processing by allowing a signal arriving with different propagation delays to be received and processed separately. Examples of the utilization of path diversity are illustrated in co-pending U.S. Patent No. 5,101,501 entitled "SOFT HANDOFF IN A CDMA CELLULAR TELEPHONE SYSTEM", and U.S. Patent No. 5,109,390 entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR TELEPHONE SYSTEM", both assigned to the assignee of the present invention and incorporated by reference herein.

FIG. 1 illustrates a transmission scheme for a multiple-carrier code division multiple access (CDMA) system in which each carrier carries a fixed fraction of the transmitted data. Variable rate frame of information bits are provided to encoder **2** which encodes the bits in accordance with a convolutional encoding format. The encoded symbols are provided to symbol repetition means **4**. Symbol repetition means **4** repeats the encoded symbols so as to provide a fixed rate of symbols out of symbol repetition means **4**, regardless of the rate of the information bits.

The repeated symbols are provided to block interleaver **6** which rearranges the sequence in which the symbols are to be transmitted. The interleaving process, coupled with the forward error correction, provides time diversity which aids in the reception and error recovery of the transmitted signal in the face of burst errors. The interleaved symbols are provided to data scrambler **12**. Data scrambler **12** multiplies each interleaved symbol by +1 or -1 according to a pseudonoise (PN) sequence. The pseudonoise sequence is provided by passing a long PN sequence generated by long code generator **8** at the chip rate through decimator **10** which selectively provides a subset of the chips of the long code sequence at the rate of the interleaved symbol stream.

The data from data scrambler **12** is provided to demultiplexer (DEMUX) **14**. Demultiplexer **14** divides the data stream into three equal sub-streams. The first sub-stream is provided to transmission subsystem **15a**, the second sub-stream to transmission subsystem **15b** and the third sub-stream to transmission subsystem **15c**. The subframes are provided to serial-to-parallel converters (BINARY TO 4 LEVEL) **16a-16c**. The outputs of serial to parallel converters **16a-16c** are quaternary symbols (2bits/symbol) to be transmitted in a QPSK modulation format

The signals from serial-to-parallel converters **16a-16c** are provided to Walsh coders **18a-18c**. In Walsh coders **18a-18c**, the signal from each converter **16a-16k** is multiplied by a Walsh sequence consisting of ±1 values. The Walsh coded data is provided to QPSK spreaders **20a-20c**, which spread the data in accordance with two short PN sequences. The short PN sequence spread signals are provided to amplifiers **22a-22b** which amplify the signals in accordance with a gain factor.

The system described above suffers from a plurality of drawbacks. First, because the data is to be provided in equal sub-streams on each of the carriers, the available numerology is limited to frames with a number of code symbols that will divide evenly by a factor of three. Table 1 below

illustrates the limited number of possible rate sets which are available using the transmission system illustrated in FIG. 1.

Walsh Function (QPSK Symbol) Rate [sps]	Number of Walsh Functions per 20ms		Length of Walsh Function [chips]	Symbol Rate [sps] (After Repetition)	Number of Symbols per 20 ms.	
1228800	24576	$3*(2^{13})$	1	2457600	49152	$3*(2^{14})$
614400	12288	$3*(2^{12})$	2	1228800	24576	$3*(2^{13})$
307200	6144	$3*(2^{11})$	4	614400	12288	$3*(2^{12})$
153600	3072	$3*(2^{10})$	8	307200	61444	$3*(2^{11})$
76800	1536	$3*(2^{9})$	16	153600	3072	$3*(2^{10})$
38400	768	$3*(2^{8})$	32	76800	1536	$3*(2^{9})$
19200	384	$3*(2^{7})$	64	38400	768	$3*(2^{8})$
9600	192	$3*(2^{6})$	128	19200	384	$3*(2^{7})$
4800	96	$3*(2^{5})$	256	9600	192	$3*(2^{6})$
2400	48	$3*(2^{4})$	512	4800	96	$3*(2^{5})$
1200	24	$3*(2^{3})$	1024	2400	48	$3*(2^{4})$
600	12	$3*(2^{2})$	2048	1200	24	$3*(2^{3})$
300	6	$3*(2^{1})$	4096	600	12	$3*(2^{2})$
150	3	$3*(2^{0})$	8192	300	6	$3*(2^{1})$

Table 1

As illustrated in Table 1, because the symbols are evenly distributed to the three carriers, the total data rate is limited by the carrier with the least power available or requiring the highest SNR. That is the total data rate is equalt to three times te data rate of the "worst" link (here the worst means the one requiring the highest SNR or having the least power avaialble). this reduces the system throughput, because the worst link's rate is always chosen as the common rate for all three carriers, which results in under utilization of the channel resource on the two better links.

Second, frequency dependent fading can severely affect one of the frequencies while having a limited effect on the remaining frequencies. This implementation is inflexible and does not allow transmission of a frame to be provided in a way that reduces the effects of the poor channel. Third, because of frequency dependent fading, the fading will typically always affectthe same groups of symbolsof each frame. Fourth, were the

implementation to be superimposed on a speech transmission system there is no good way to balance the loads carried on the different frequencies on a frame by frame basis in the face of variable speech activities in each frame. This results in loss in total system throughput. And fifth, for a system with only three frequency channels, with the implementation described, there is no method of separating the speech and data so as to provide the data on one frequency or set of frequencies and the speech on a different frequency or set of frequencies. This results in a loss of system throughput as mentioned above.

Therefore, there is a need felt for an improved multi-carrier CDMA communication system which offers greater flexibility in numerology and load balancing, better resolution in data rates supported, and which offers superior performance in the face of frequency dependent fading and uneven loading.

SUMMARY OF THE INVENTION

In one aspect the invention provides a transmitter for transmitting data at a data rate in a plurality of channels each having a capacity less than the data rate, the transmitter comprising: a controller for determining the capacity of each of a plurality channels and selecting a data rate for each channel depending on the determined capacity; a plurality of transmission subsystems responsive to the controller and each associated with a respective one of the plurality of channels for scrambling encoded data with codes unique to the channel for transmission in the channel; and a variable demultilplexer responsive to the controller for demultiplexing the encoded data into the plurality of transmission subsystems at a demultiplexing rate derived from the data rates selected for the channels by the controller.

In another aspect the invention provides a receiver comprising: a receiving circuit for receiving signals simultaneously in a plurality of channels each of which signals define scrambled encoded symbols which together represent data from a common origin; a controller for determining a symbol rate for the signals in each channel; a plurality of receiving subsystems responsive to the controller and each associated with a respective one of the plurality of channels for descrambling encoded symbols with codes unique to the channel to enable the data to be extracted therefrom; and a variable multilplexer responsive to the controller for multiplexing the data from the plurality of receiving subsystems at a

multiplexing rate derived from the symbol rates determined for the channels by the controller onto an output.

In a further aspect the invention provides a wireless transmitter, comprising: encoder for receive a set of information bits and encoding said information bits to provide a set of code symbols; and a transmission subsystem for receiving said code symbols and for providing a subset of said code symbols on a first carrier frequency and the remaining symbols on at least one additional carrier frequency.

The invention also provides a method of transmitting data at a data rate in a plurality of channels each having a capacity less than the data rate, the method comprising: determining the capacity of each of a plurality channels and selecting a data rate for each channel depending on the determined capacity; scrambling encoded data with codes unique to the channel for transmission in the channel; and demultiplexing the encoded data into the plurality of channels at a demultiplexing rate derived from the data rates selected for the channels by the controller.

The invention further provides a method of receiving data, the method comprising: receiving signals simultaneously in a plurality of channels each of which signals define scrambled encoded symbols which together represent data from a common origin; determining a symbol rate for the signals in each channel; descrambling encoded symbols in each channel with codes unique to the channel to enable the data to be extracted therefrom; and multiplexing the descrambled data from the plurality of channels at a multiplexing rate derived from the symbol rates determined for the channels.

To better utilize the channel resource, it's necessary to be able to transmit a different data rate on each carrier according to the channel condition and the available power on each channel. One way of doing this is by changing the ratio of the inverse-multiplexing on to each of the carriers. Instead of distributing the symbols with a ratio of 1:1:1, a more arbitrary ratio can be used together with different repetition schemes as long as the resulted symbol rate on each carrier is a factor of some Walsh function rate. Walsh function rate can be 1228800, 614400, 307200,..., 75 for Walsh function length from 1 to 16384.

Given the Walsh function length, if the symbol rate is lower than the Walsh function rate, symbol repetition is used to "match" the rate. The repetition factor can be any number, integer or fractional. It will be understood by one skilled in the art that when repetition is present, the total transmit power can be proportionately reduced to keep the code symbol

energy constant. The Walsh function length may or may not be the same on the three carriers, depending on whether we need to save code channels. For example, if the supportable code symbol rate on the three channels are 153600 sps, 30720 sps and 102400 sps (for rate 1/2 coding, these correspond to data rates of 76.8 kbps, 15.36 kbps and 51.2 kbps, respectively - the total data rate is 143.36 kbps), then the inverse-multiplexing ratio will be 15:3:10.

If a Walsh function of length 8 is used for all three channels (assuming QPSK modulation with a QPSK symbol rate of 153.6 Ksps), then each code symbol is transmitted twice, 10 times, and three times on the three channels, respectively. Additional time diversity can be obtained if the repeated symbols are further interleaved. In an alternative embodiment, different Walsh function lengths are used. For example, Walsh functions for the three channels in the example of above of length 16, 16 and 8 respectively can be used, with each code symbol transmitted once on the first channel, five times on the second, and three times on the third.

The above approach does not affect the encoder since it has to be able to handle the highest data rate anyway. All that is changed is the number of data octets at the encoder input. However, this approach does have an impact on the implementation of the interleaver because the interleaver will have many possible sizes (in terms of number of symbols) if all combinations of data rates on the three channels are allowed. One alternative to the above approach which mitigates this problem is to inverse-multiplex the code symbols out of the encoder to the three carriers directly and perform interleaving of repeated code symbols on each channel separately. This simplifies the numerology and reduces the number of possible interleaver sizes on each channel.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below of embodiments of the invention when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a block diagram illustrating a multiple frequency CDMA communication system with fixed rates and carriers;

FIG. 2 is a block diagram illustrating a transmission system embodying the present invention;

FIG. 3 is a block diagram illustrating a receiver system embodying the present invention; and

FIG. 4 is a table of code channel Walsh symbols in a traditional IS-95 CDMA communication system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 2, which is a block diagram illustrating a transmission system embodying the present invention, the first operation to be performed is to determine the amount of data which can be supported on each of the carriers. Three such carriers are illustrated in FIG. 2, though one skilled in the art will realize that the present invention is easily extended to any number of carriers. Control processor **50** based on a set of factors such as the loading on each of the carriers, the amount of data queued for transmission to the mobile station and the priority of the information to be transmitted to the mobile station determines the rate of data transmission on each of the carriers.

After having selected the data rate to be transmitted on each of the carriers, control processor **50** selects a modulation format that is capable of transmitting data at the selected rate. In the exemplary embodiment, different length Walsh sequences are used to modulate the data depending on the rate of the data to be transmitted. The use of different length Walsh sequences selected to modulate the data depending on the rate of the data to be transmitted is described in detail in co-pending U.S. Patent Application Serial No. 08/654,443, filed May 28, 1996, entitled "HIGH RATE DATA WIRELESS COMMUNICATION SYSTEM", which is assigned to the assignee of the present invention and incorporated by reference herein. In an alternative embodiment, the high rate data can be supported by bundling of CDMA channels as described in the aforementioned Patent Applications Serial Nos. 08/431,180 and 08/838,240.

Once the rates which will be supported on each of the carriers is selected then control processor **50** calculates an inverse multiplexing ratio that will determine the amount of each transmission that will be carried on each of the carriers. For example, if the supportable code symbol rate on the three channels are 153600 sps, 30720 sps and 102400 sps (for rate 1/2 coding, these correspond to data rates of 76.8 kbps, 15.36 kbps and 51.2 kbps, respectively - the total data rate is 143.36 kbps), then the inverse-multiplexing ratio will be 15:3:10.

In the exemplary embodiment, frames of information bits are provided to frame formatter **52**. In the exemplary embodiment, formatter **52** generates and appends to the frame a set of cyclic redundancy check (CRC) bits. In addition, formatter **52** appends a predetermined set of tail bits. The implementation and design of frame formatters are well known in the art, an example of a typical frame formatter is described in detail in U.S. Patent No. 5,600,754, entitled "METHOD AND SYSTEM FOR THE ARRANGEMENT OF VOCODER DATA FOR THE MASKING OF TRANSMISSION CHANNEL INDUCED ERRORS", which is assigned to the assignee of the present invention and incorporated by reference herein.

The formatted data is provided to encoder **54**. In the exemplary embodiment, encoder **54** is a convolutional encoder, though the present invention can be extended to other forms of encoding. A signal from control processor **50** indicates to encoder **54** the number of bits to be encoded in this transmission cycle. In the exemplary embodiment, encoder **54** is a rate 1/4 convolutional encoder with a constraint length of 9. It should be noted that because of the additional flexibility provided by the present invention, essentially any encoding format can be used.

The encoded symbols from encoder **54** are provided to variable ratio de-multiplexer **56**. Variable ratio de-multiplexer **56** provides the encoded symbols to a set of outputs based on a symbol output signal provided by control processor **50**. In the exemplary embodiment, there are three carrier frequencies and control processor **50** provides a signal indicative of the number of encoded symbols to be provided on each of the three outputs. As one skilled in the art will appreciate, the present invention is easily extended to an arbitrary number of frequencies.

The encoded symbols provided on each of the outputs of variable ratio de-multiplexer **56** are provided to a corresponding symbol repetition means **58a-58c**. Symbol repetition means **58a-58c** generate repeated versions of the encoded symbols so that the resultant symbol rate matches with the rate of data supported on that carrier and the in particular matches Walsh function rate used on that carrier. The implementation of repetition generators **58a-58c** is known in the art and an example of such is described in detail in U.S. Patent No. 5,629,955, entitled "Variable Response Filter", which is assigned to the assignee of the present invention and incorporated by reference herein. Control processor **50** provides a separate signal to each repetition generator **58a-58c** indicating the rate of symbols on each carrier or alternatively the amount of repetition to be provided on each carrier. In response to the signal from control processor **50**, repetition means **58a-58c**

generate the requisite numbers of repeated symbols to provide the designated symbol rates. It should be noted that in the preferred embodiment, the amount of repetition is not limited to integer number wherein all symbols are repeated the same number of times. A method for providing non-integer repetition is described in detail in co-pending U.S. Patent Application Serial No. 08/886,815, filed March 26, 1997, entitled "METHOD AND APPARATUS FOR TRANSMITTING HIGH SPEED DATA IN A SPREAD SPECTRUM COMMUNICATIONS SYSTEM", which is assigned to the assignee of the present invention and incorporated by reference herein.

The symbols from repetition generators **58a-58c** are provided to a corresponding one of interleavers **60a-60c** which reorders the repeated symbols in accordance with a predetermined interleaver format. Control processor **50** provides an interleaving format signal to each of interleavers **60a-60c** which indicates one of a predetermined set of interleaving formats. In the exemplary embodiment, the interleaving format is selected from a predetermined set of bit reversal interleaving formats.

The reordered symbols from interleavers **60a-60c** are provided to data scramblers **62a-62c**. Each of data scramblers **62a-62c** changes the sign of the data in accordance with a pseudonoise (PN) sequence. Each PN sequence is provided by passing a long PN code generated by long code or PN generator **82** at the chip rate through a decimator **84a-84c**, which selectively provides ones of the spreading symbols to provide a PN sequence at a rate no higher than that provided by PN generator **82**. Because the symbol rate on each carrier may be different from one another, the decimation rate of decimators **84a-84c** may be different. Decimators **84a-84c** are sample and hold circuits which sample the PN sequence out of PN generator **82** and continue to output that value for a predetermined period. The implementation of PN generator **82** and decimators **84a-84c** are well known in the art and are described in detail in the aforementioned U.S. Patent No. 5,103,459. Data scramblers **62a-62c** exclusively-OR the binary symbols from interleavers **60a-60c** with the decimated pseudonoise binary sequences from decimators **84a-84c**.

The binary scrambled symbol sequences are provided to serial to parallel converters (BINARY TO 4-LEVEL) **64a-64c**. Two binary symbols provided to converters **64a-64c** are mapped to a quaternary constellation with values (±1, ±1). The constellation values are provided on two outputs from converters **62a-62c**. The symbol streams from converters **64a-64c** are separately provided to Walsh spreaders **66a-66c**.

There are many methods of providing high speed data in a code division multiple access communication system. In the preferred embodiment, the Walsh sequence length is varied in accordance with the rate of the data to be modulated. Shorter Walsh sequences are used to modulate higher speed data and longer Walsh sequences are used to modulate lower rate data. For example, a 64 bit Walsh sequence can be used to transmit data at 19.2 Ksps. However, a 32 bit Walsh sequence can be used to modulate data at 38.4 Ksps.

A system describing variable length Walsh sequence modulation is described in detail in co-pending U.S. Patent Application Serial No. 08/724,281, entitled "HIGH DATA RATE SUPPLEMENTAL CHANNEL FOR CDMA TELECOMMUNICATIONS SYSTEM", filed January 15, 1997 and incorporated by reference herein. The length of the Walsh sequences used to modulate the data depend on the rate of the rate of the data to be transmitted. FIG. 4 illustrates the Walsh functions in a traditional IS-95 CDMA system.

In the preferred embodiment of the invention, the number of Walsh channels allocated for the high-rate data can be any value 2^N where N = {2, 3, 4, 5, 6}. The Walsh codes used by Walsh coders **66a-66c** are $64/2^N$ symbols long, rather than the 64 symbols used with the IS-95 Walsh codes. In order for the high-rate channel to be orthogonal to the other code channels with 64-symbol Walsh codes, 2^N of the possible 64 quaternary-phase channels with 64-symbol Walsh are eliminated from use. Table I provides a list of the possible Walsh codes for each value of N and the corresponding sets of allocated 64-symbol Walsh codes.

N	$Walsh_i$	Allocated 64-Symbol Walsh Codes
2	+,+,+,+,+,+,+,+,+,+,+,+,+,+,+,+	0, 16, 32, 48
	+,−,+,−,+,−,+,−,+,−,+,−,+,−,+,−	1, 17, 33, 49
	+,+,−,−,+,+,−,−,+,+,−,−,+,+,−,−	2, 18, 34, 50
	+,−,−,+,+,−,−,+,+,−,−,+,+,−,−,+	3, 19, 35, 51
	+,+,+,+,−,−,−,−,+,+,+,+,−,−,−,−	4, 20, 36, 52
	+,−,+,−,−,+,−,+,+,−,+,−,−,+,−,+	5, 21, 37, 53
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	+,−,−,+,−,+,+,−,+,−,−,+,−,+,+,−	7, 23, 39, 55
	+,+,+,+,+,+,+,+,−,−,−,−,−,−,−,−	8, 24, 40, 56
	+,−,+,−,+,−,+,−,−,+,−,+,−,+,−,+	9, 25, 41, 57
	+,+,−,−,+,+,−,−,−,−,+,+,−,−,+,+	10, 26, 42, 58
	+,−,−,+,+,−,−,+,−,+,+,−,−,+,+,−	11, 27, 43, 59
	+,+,+,+,−,−,−,−,−,−,−,−,+,+,+,+	12, 28, 44, 60
	+,−,+,−,−,+,−,+,−,+,−,+,+,−,+,−	13, 29, 45, 61
	+,+,−,−,−,−,+,+,−,−,+,+,+,+,−,−	14, 30, 46, 62
	+,−,−,+,−,+,+,−,−,+,+,−,+,−,−,+	15, 31, 47, 63
3	+,+,+,+,+,+,+,+	0, 8, 16, 24, 32, 40, 48, 56
	+,−,+,−,+,−,+,−	1, 9, 17, 25, 33, 41, 49, 57
	+,+,−,−,+,+,−,−	2, 10, 18, 26, 34, 42, 50, 58
	+,−,−,+,+,−,−,+	3, 11, 19, 27, 35, 43, 51, 59
	+,+,+,+,−,−,−,−	4, 12, 20, 28, 36, 44, 52, 60
	+,−,+,−,−,+,−,+	5, 13, 21, 29, 37, 45, 53, 61
	+,+,−,−,−,−,+,+	6, 14, 22, 30, 38, 46, 54, 62
	+,−,−,+,−,+,+,−	7, 15, 23, 31, 39, 47, 55, 63
4	+,+,+,+	0, 4, 8,…,60
	+,−,+,−	1, 5, 9, …,61
	+,+,−,−	2, 6, 10, …,62
	+,−,−,+	3, 7, 11, …,63
5	+,+	0, 2, 4,…,62
	+,−	1, 3, 5, …,63
6	+	0, 1, 2,…,63

Table I.

The + and – indicate a positive or negative integer value, where the preferred integer is 1. As is apparent, the number of Walsh symbols in each Walsh code varies as N varies, and in all instances is less than the number

of symbols in the IS-95 Walsh channel codes. Regardless of the length of the Walsh code, in the described embodiment of the invention the symbols are applied at a rate of 1.2288 Megachips per second (Mcps). Thus, shorter length Walsh codes are repeated more often. Control processor **50** provides a signal to Walsh coding elements **66a-66c** which indicates the Walsh sequence to be used to spread the data.

Alternative methods for transmitting high rate data in CDMA communication system also include methods generally referred to as channel bundling techniques. The present invention is equally applicable to the channel bundling methods for providing high speed data in a CDMA communciation system. One method of providing channel bundled data is to provide a plurality of Walsh channels for use by a signal user. This method is described in detail in the aforementioned U.S. Patent Application Serial No. 08/739,482. An alternative channel bundling technique is to provide the user with use of one Walsh code channel but to differentiate the signals from one another by means of different scrambling signals as described in detail in co-pending U.S. Patent Application Serial No. 08/838,240.

The Walsh spread data is provided to PN spreaders **68a-68c**, which apply a short PN sequence spreading on the output signals. In the exemplary embodiment, the PN spreading is performed by means of a complex multiplication as described in detail in the aforementioned co-pending U.S. Patent Application Serial No. 08/784,281. Data channels D_I and D_Q are complex multiplied, as the first real and imaginary terms respectively, with spreading codes PN_I and PN_Q, as the second real and imaginary terms respectively, yielding in-phase (or real) term X_I and quadrature-phase (or imaginary) term X_Q. Spreading codes PN_I and PN_Q are generated by spreading code generators **67** and **69**. Spreading codes PN_I and PN_Q are applied at 1.2288 Mcps. Equation (1) illustrates the complex multiplication performed.

$$(X_I + jX_Q) = (D_I + jD_Q)(PN_I + jPN_Q) \qquad (1)$$

In-phase term X_I is then low-pass filtered to a 1.2288 MHz bandwidth (not shown) and upconverted by multiplication with in-phase carrier $COS(\omega_c t)$. Similarly, quadrature-phase term X_Q is low-pass filtered to a 1.2288 MHz bandwidth (not shown) and upconverted by multiplication with quadrature-phase carrier $SIN(\omega_c t)$. The upconverted X_I and X_Q terms are summed yielding forward link signal s(t). The complex multiplication

allows quadrature-phase channel set to remain orthogonal to the in-phase channel set and therefore to be provided without adding additional interference to the other channels transmitted over the same path with perfect receiver phase recovery.

The PN spread data is, then, provided to filters **70a-70c** which spectrally shape the signals for transmission. The filtered signals are provided to gain multipliers **72a-72c**, which amplify the signals for each carrier. The gain factor is supplied to gain elements **72a-72c** by control processor **50**. In the exemplary embodiment, control processor **50** selects the gain factor for each carrier in accordance with the channel condition and the rate of the information data to be transmitted on that carrier. As is known by one skilled in the art, data that is transmitted with repetition can be transmitted with lower symbol energy than data without repetition.

The amplified signals are provided to an optional switch **74**. Switch **74** provides the additional flexibility of channel hopping the data signals onto different carriers. Typically, switch **74** is only used when the number of carriers actually used to transmit the signal is smaller that the total number of possible carriers (3 in the present example).

The data is passed by switch **74** to carrier modulators **76a-76c.** Each of carrier modulators **76a-76c** upconvert the data to a different predetermined frequency. The upconverted signals are provided to transmitter **78** where they are combined with other similarly processed signals, filtered and amplified for transmission through antenna **80**. In the exemplary embodiment, the amplified frequency upon which each of the signals are transmitted varies with time. This provides additional frequency diversity for the transmitted signals. For example a signal that is currently being transmitted through carrier modulator **76a** will at predetermined time interval be switched so as to be transmitted on a different frequency through carrier modulators **76b** or **76c**. In accordance with a signal from control processor **50**, switch **74** directs an amplified input signal from gain multiplier **72a-72c** to an appropriate carrier modulator **76a-76c**.

Turning to FIG. 3, a receiver system embodying the present invention is illustrated. The signal received at antenna **100** is passed to receiver (RCVR) **102**, which amplifies and filters the signal before providing it to switch **104**. The data is provided through switch **104** to an appropriate carrier demodulator **106a-106c**. It will be understood by one skilled in the art that although the receiver structure is described for the reception of a signal transmitted on three frequencies, the present invention can easily be

extended to an arbitrary number of frequencies consecutive to one another or not.

When the carriers on which the data is transmitted are rotated or hopped to provide additional frequency diversity, switch **104** provides the received signal to a selected carrier demodulator **106a-106c** in response to a control signal from control processor **125**. When the carrier frequencies are not hopped or rotated, then switch **104** is unnecessary. Each of carrier demodulators **106a-106c** Quaternary Phase Shift Keying (QPSK) demodulate the received signal to baseband using a different downconversion frequency to provide a separate I and Q baseband signals.

The downconverted signals from each of carrier demodulators **106a-106c** are provided to a corresponding PN despreader **108a-108c** which removes the short code spreading from the downconverted data. The I and Q signals are despread by complex multiplication with a pair of short PN code. The PN despread data is provided to Walsh demodulators **110a-110c**, which uncover the data in accordance with the assigned code channel sequences. In the exemplary embodiment, Walsh functions are used in the generation and reception of the CDMA signals but other forms of code channel generation are equally applicable. Control processor **125** provides a signal to Walsh demodulators **110a-110c** indicating the Walsh sequences to be used to uncover the data.

The Walsh despread symbols are provided to parallel-to-serial converters (4-LEVEL TO BINARY) **112a-112c**, which map the 2-dimensional signal into a 1-dimensional signal. The symbols are then provided to descramblers **114a-114c**. Descramblers **114a-114c** descramble the data in accordance with a decimated long code sequence generated as described with respect to the decimated long code sequences used to scramble the data in FIG. 2.

The descrambled data is provided to de-interleavers (DE-INT) **116a-116c**. De-interleavers **116a-116c** reorder the symbols in accordance with selected de-interleaver formats that are provided by control processor **125**. In the exemplary embodiment, control processor **125** provides a signal indicative of the size of the deinterleaver and the scheme of de-interleaving to each of de-interleavers **116a-116c**. In the exemplary embodiment, the de-interleaving scheme is selected from a predetermined set of bit reversal de-interleaving schemes.

The de-interleaved symbols are then provided to symbol combiners **118a-118c** which coherently combine those repeatedly transmitted symbols. The combined symbols (soft decisions) are then provided to variable ratio

multiplexer **120** which reassembles the data stream and provides the reassembled data stream to decoder **122**. In the exemplary embodiment decoder **122** is a maximum likelihood decoder, the implementation of which is well known in the art. In the exemplary embodiment, decoder **122** contains a buffer (not shown) which waits until an entire frame of data has been provided to it before beginning the decoding process. The decoded frame is provided to CRC check means **124** which determines whether the CRC bits check and if so provides them to the user otherwise an erasure is declared.

Having thus described the invention by reference to a preferred embodiment it is to be well understood that the embodiment in question is exemplary only and that modifications and variations such as will occur to those possessed of appropriate knowledge and skills may be made without departure from the spirit and scope of the invention as set forth in the appended claims and equivalents thereof.

I CLAIM:

CLAIMS

1. A transmitter for transmitting data at a data rate in a plurality of channels each having a capacity less than the data rate, the transmitter comprising;

a controller for determining the capacity of each of a plurality channels and selecting a data rate for each channel depending on the determined capacity;

a plurality of transmission subsystems responsive to the controller and each associated with a respective one of the plurality of channels for scrambling encoded data with codes unique to the channel for transmission in the channel; and

a variable demultilplexer responsive to the controller for demultiplexing the encoded data into the plurality of transmission subsystems at a demultiplexing rate derived from the data rates selected for the channels by the controller.

2. A transmitter as claimed in claim 1, further comprising an encoder for generating the encoded data from frames of data input thereto.

3. A transmitter as claimed in claim 1 or 2, wherein each transmission subsystem comprises a symbol repetition unit for repeating symbols to output the same at a rate corresponding to the rate selected for the channel by the controller.

4. A transmitter as claimed in claim 3, wherein each transmission subsystem comprises an interleaving unit for reordering the repeated symbols depending on an interleaving format determined by the controller.

5. A transmitter as claimed in claim 4, further comprising a long code generator for generating a respective long code for each channel; and

in each transmission subsystem, a scrambler for scrambling the reordered symbols using the respective code for the channel.

6. A transmitter as claimed in claim 5, wherein the long code generator comprises for each channel a decimator unit for decimating a generated long code at a decimation rate determined by the controller so as to produce the respective long codes for each channel.

7. A transmitter as claimed in claim 6, further comprising variable coding units in each transmission subsystem for modulating the scrambled symbols from the scrambler.

8. A transmitter as claimed in claim 7, wherein the coding units are arranged to modulate the scrambled symbols with a respective walsh code.

9. A transmitter as claimed in claim 7 or 8, further comprising a pseudo noise spreader in each channel for spreading the modulated symbols.

10. A transmitter as claimed in any preceding claim, further comprising:

a switch; and

a plurality of carrier modulators, wherein the switch is responsive to the controller for switching the scrambled data from the plurality of transmission subsystems between the plural carrier modulators for modulation of the signals onto different carriers at different times.

11. A receiver comprising:

a receiving circuit for receiving signals simultaneously in a plurality of channels each of which signals define scrambled encoded symbols which together represent data from a common origin;

a controller for determining a symbol rate for the signals in each channel;

a plurality of receiving subsystems responsive to the controller and each associated with a respective one of the plurality of channels for descrambling encoded symbols with codes unique to the channel to enable the data to be extracted therefrom; and

a variable multilplexer responsive to the controller for multiplexing the data from the plurality of receiving subsystems at a multiplexing rate derived from the symbol rates determined for the channels by the controller onto an output.

12. A receiver as claimed in claim 11, further comprising an decoder for decoding the encoded data output from the multiplexer into frames of data.

13. A receiver as claimed in claim 11 or 12, further comprising a pseudo noise despreader in each channel for despreading the scrambled encoded symbols.

14. A receiver as claimed in claim 13, further comprising variable decoding units in each receiving subsystem for demodulating the despread symbols from the despreader.

15. A receiver as claimed in claim 14, wherein the decoding units are arranged to demodulate the despread symbols with a respective walsh code.

16. A receiver as claimed in claim 15, further comprising, in each receiving subsystem, a descrambler for descrambling the despread symbols using a respective long code for the channel.

17. A receiver as claimed in claim 16, wherein each receiving subsystem comprises an deinterleaving unit for reordering the repeated symbols depending on an interleaving format determined by the controller.

18. A receiver as claimed in claim 17, wherein each receiving subsystem comprises a symbol combiner for combining symbols to output the same to the demultiplexer at a rate corresponding to the rate determined for the channel by the controller.

19. A receiver as claimed in any of claims 11 to 18, further comprising:

a switch; and

a plurality of carrier demodulators, wherein the switch is responsive to the controller for switching the received signals between the plural carrier demodulators for demodulation of the signals into different receiving subsystems at different times.

20. A wireless transmitter, comprising:

encoder for receive a set of information bits and encoding said information bits to provide a set of code symbols; and

transmission subsystem for receiving said code symbols and for providing a subset of said code symbols on a first carrier frequency and the remaining symbols on at least one additional carrier frequency.

21. A method of transmitting data at a data rate in a plurality of channels each having a capacity less than the data rate, the method comprising;

determining the capacity of each of a plurality channels and selecting a data rate for each channel depending on the determined capacity;

scrambling encoded data with codes unique to the channel for transmission in the channel; and

demultiplexing the encoded data into the plurality of channels at a demultiplexing rate derived from the data rates selected for the channels by the controller.

22. A method as claimed in claim 21, further comprising an encoder for generating the encoded data from frames of data input thereto.

23. A method as claimed in claim 21 or 22, further comprising repeating symbols for each channel to output the same at a rate corresponding to the rate selected for the channel.

24. A method as claimed in claim 23, further comprising reordering the repeated symbols depending on a determined interleaving format.

25. A method as claimed in claim 24, further comprising

generating a respective long code for each channel; and

scrambling the reordered symbols in each transmission subsystem using the respective code for the channel.

26. A method as claimed in claim 25, wherein the long code is generated for each by decimating a generated long code at a determined decimation rate for each channel.

27. A method as claimed in claim 26, further comprising for modulating the scrambled symbols with a code.

28. A method as claimed in claim 27, the scrambled symbols are modulated with a respective walsh code.

29. A method as claimed in claim 27 or 28, further comprising spreading the modulated symbols with pseudo noise.

30. A method as claimed in any of claims 21 to 29, further comprising modulating the scrambled data onto different carriers at different times.

31. A method of receiving data, the method comprising:

receiving signals simultaneously in a plurality of channels each of which signals define scrambled encoded symbols which together represent data from a common origin;

determining a symbol rate for the signals in each channel;

descrambling encoded symbols in each channel with codes unique to the channel to enable the data to be extracted therefrom; and

multiplexing the descrambled data from the plurality of channels at a multiplexing rate derived from the symbol rates determined for the channels.

32. A method of receiving data as claimed in claim 31, further comprising decoding the multiplexed encoded data into frames of data.

33. A method of receiving data as claimed in claim 31 or 32, further comprising despreading the scrambled encoded symbols using a pseudo noise code.

34. A method of receiving data as claimed in claim 33, further comprising demodulating the despread symbols by way of variable decoding.

35. A method of receiving data as claimed in claim 34, wherein the despread symbols are demodulated with a respective walsh code.

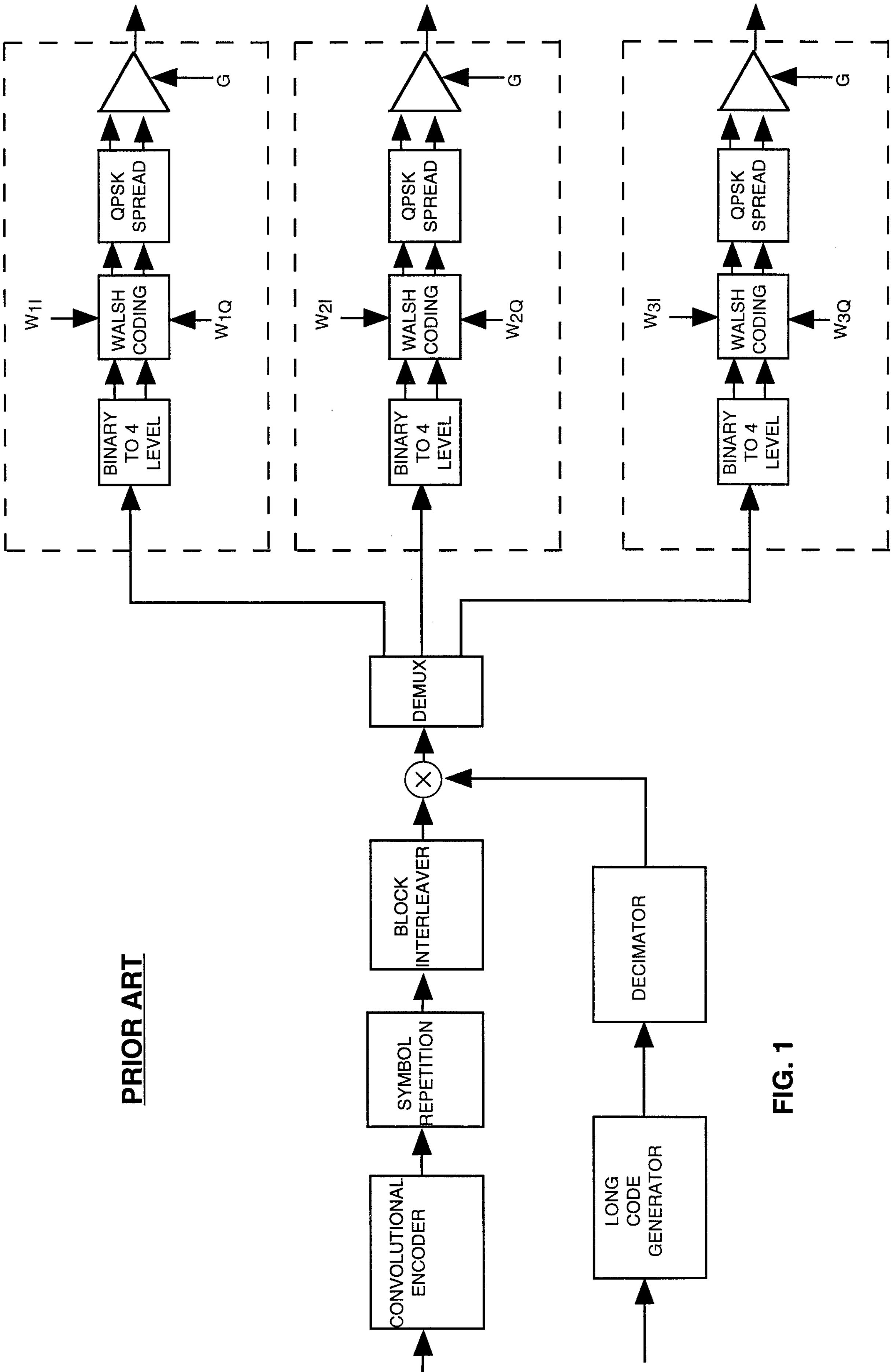
36. A method of receiving data as claimed in claim 35, further comprising descrambling the despread symbols in each channel using a respective long code for the channel.

37. A method of receiving data as claimed in claim 36, further comprising reordering the repeated symbols depending on a determined interleaving format.

38. A method of receiving data as claimed in claim 37, further comprising combining symbols in a channel before demultiplexing the same at a rate corresponding to the rate determined for the channel.

39. A method of receiving data as claimed in any of claims 31 to 38, further comprising:

demodulating the signals in different channels at different times.



PRIOR ART

FIG. 1

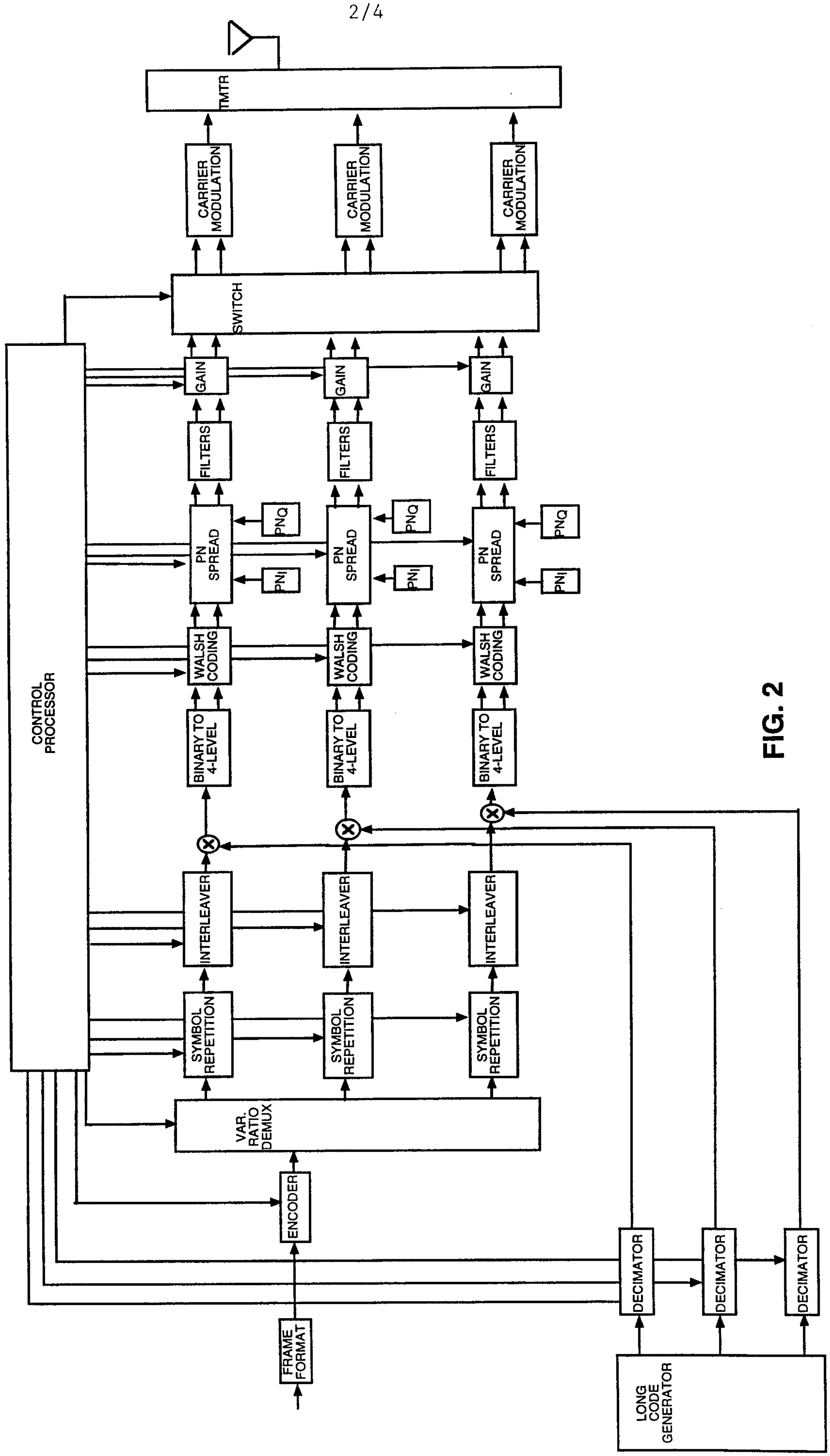

TMTR
CARRIER MODULATION
CARRIER MODULATION
CARRIER MODULATION
SWITCH
GAIN
GAIN
GAIN
FILTERS
FILTERS
FILTERS
PN SPREAD
PN SPREAD
PN SPREAD
PNQ
PNI
PNQ
PNI
PNQ
PNI
WALSH CODING
WALSH CODING
WALSH CODING
BINARY TO 4-LEVEL
BINARY TO 4-LEVEL
BINARY TO 4-LEVEL
CONTROL PROCESSOR
INTERLEAVER
INTERLEAVER
INTERLEAVER
SYMBOL REPETITION
SYMBOL REPETITION
SYMBOL REPETITION
VAR. RATIO DEMUX
ENCODER
FRAME FORMAT
DECIMATOR
DECIMATOR
DECIMATOR
LONG CODE GENERATOR

FIG. 2

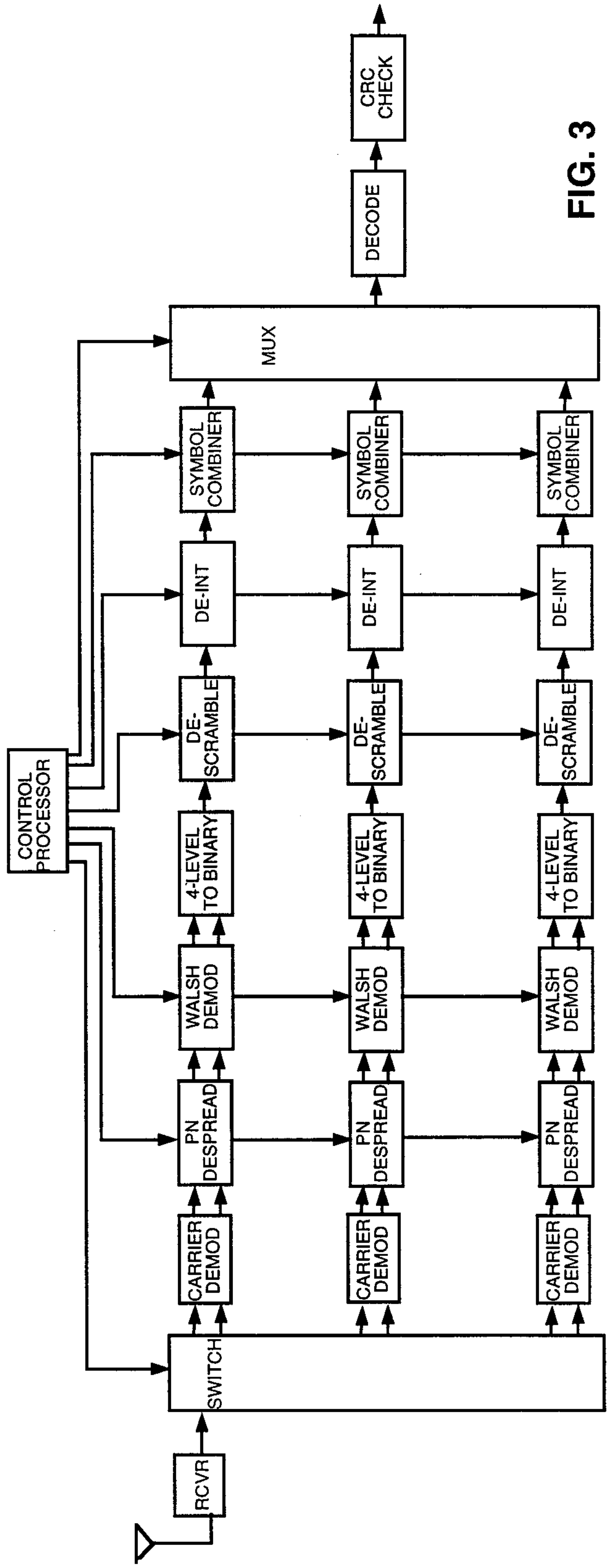

RCVR
SWITCH
CONTROL PROCESSOR
CARRIER DEMOD
PN DESPREAD
WALSH DEMOD
4-LEVEL TO BINARY
DE-SCRAMBLE
DE-INT
SYMBOL COMBINER
MUX
DECODE
CRC CHECK

FIG. 3

Walsh Chip within a Walsh Function

Walsh Function Index	0 1 2 3	4 5 6 7	8 9 10 11	12 13 14 15	16 17 18 19	20 21 22 23	24 25 26 27	28 29 30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48 49 50 51	52 53 54 55	56 57 58 59	60 61 62 63
0	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
1	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101
2	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011
3	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110
4	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111
5	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010
6	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100
7	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001
8	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111
9	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010
10	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100
11	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001
12	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000
13	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101
14	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011
15	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110
16	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111
17	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010
18	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100
19	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001
20	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000
21	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101
22	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011
23	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110
24	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000
25	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101
26	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011
27	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110
28	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111
29	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010
30	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100
31	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001
32	0000	0000	0000	0000	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111
33	0101	0101	0101	0101	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010
34	0011	0011	0011	0011	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100
35	0110	0110	0110	0110	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001
36	0000	1111	0000	1111	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000
37	0101	1010	0101	1010	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101
38	0011	1100	0011	1100	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011
39	0110	1001	0110	1001	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110
40	0000	0000	1111	1111	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000
41	0101	0101	1010	1010	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101
42	0011	0011	1100	1100	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011
43	0110	0110	1001	1001	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110
44	0000	1111	1111	0000	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111
45	0101	1010	1010	0101	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010
46	0011	1100	1100	0011	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100
47	0110	1001	1001	0110	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001
48	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111	0000	0000	0000	0000
49	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010	0101	0101	0101	0101
50	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100	0011	0011	0011	0011
51	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001	0110	0110	0110	0110
52	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000	0000	1111	0000	1111
53	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101	0101	1010	0101	1010
54	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011	0011	1100	0011	1100
55	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110	0110	1001	0110	1001
56	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000	0000	0000	1111	1111
57	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101	0101	0101	1010	1010
58	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011	0011	0011	1100	1100
59	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110	0110	0110	1001	1001
60	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111	0000	1111	1111	0000
61	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010	0101	1010	1010	0101
62	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100	0011	1100	1100	0011
63	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001	0110	1001	1001	0110

FIG. 4